EXHIBIT A

Continuous-wave radar

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Continuous-wave radar is a type of radar system where a known stable frequency continuous wave radio energy is transmitted and then received from any reflecting objects.[1] Continuous wave (CW) radar uses Doppler, which renders the radar immune to interference from large stationary objects and slow moving clutter.[2]

CW radar systems are used at both ends of the range spectrum.

- Inexpensive radio-altimeters, proximity sensors and sport accessories that operate from a few dozen feet to several kilometers
- Costly early warning CW angle track (CWAT) radar operating beyond 100km for use with surface to air missile systems

Contents

Operation

There are two types of continuous wave radar.

- Unmodulated continuous wave
- Modulated continuous wave

There are two different antenna configurations used with continuous wave radar.

- Monostatic radar
- Bistatic radar

The main advantage of CW radar is that energy is not pulsed so these are much simpler to manufacture and operate. They have no minimum or maximum range, although the broadcast power level imposes a practical limit on range. Continuous wave radar maximize total power on a target because the transmitter is broadcasting continuously.

The military uses continuous-wave radar to guide semi-active radar homing (SARH) air-to-air missiles, such as the U.S. AIM-7 Sparrow and standard missile. The launch aircraft *illuminates* the target with a CW radar signal, and the missile homes in on the reflected radar waves. Since the missile is moving at high velocities relative to the aircraft, there is a strong Doppler shift. Most modern air combat radars, even pulse Doppler sets, have a CW function for missile guidance purposes.

Maximum distance in a continuous wave radar is determined by the overall bandwidth and transmitter power. This bandwidth is determined by two factors.

- Transmit energy density (watts per Hertz)
- Receiver filter size (bandwidth divided by the total number of filters)

Doubling transmit power increases distance performance by about 20%. Reducing the total FM transmit noise by half has the same effect.

Frequency domain receivers used for continuous wave Doppler radar receivers are very different from conventional radar receivers. The receiver consists of a bank of filters, usually more than 100. The number of filters determines the maximum distance performance.

Doubling the number of receiver filters increases distance performance by about 20%. Maximum distance performance is achieved when receiver filter size is equal to the maximum FM noise riding on the transmit signal. Reducing receiver filter size below average amount of FM transmit noise will not improve range performance.

A CW radar is said to be *matched* when the receiver filter size matches the RMS bandwidth of the FM noise on the transmit signal.

Unmodulated Continuous Wave

This kind of radar can cost less than $100. Return frequencies are shifted away from the transmitted frequency based on the Doppler effect when objects are moving. There is no way to evaluate distance. This type of radar is typically used with competition sports, like golf, tennis, baseball, and NASCAR.

The transmitter is the strongest source of RF energy in the vicinity of the receiver unless there is a large physical barrier along the line of sight, such as a mountain. There must be a strong Doppler shift between the receiver and the reflector, otherwise the bleed-through signal reaching the receive antenna from the transmit antenna will overwhelm the reflected signal arriving at the receiver.

Continuous wave radar with no FM modulation only detects moving targets, as stationary targets (along the line of sight) will not cause a Doppler shift. Reflected signals from stationary and slow-moving objects are masked by the transmit signal, which overwhelms reflections from slow-moving objects during normal operation.

Modulated Continuous Wave

Frequency-modulated (FM) continuous wave radar are capable of determining distance. This increases reliability by providing distance measurement along with speed measurement, which is essential when there is more than one source of reflection arriving at the radar antenna.

Distance measurement is implemented using a technique known as **frequency modulated continuous-wave radar**. In this system the signal is not a continuous fixed frequency, but varies up and down over a fixed period of time. Range is determined by evaluating the frequency-spread of the received signal.

FM modulation is used with CW radar altimeters used with aircraft, CW early warning radar, and proximity sensors. Doppler shift is not always required for detection when FM modulation is used.

The transmitter frequency can slew up and down as follows.

- Sine wave, like air raid siren
- Sawtooth wave, like the chirp from a bird
- Triangle wave, like police siren in the US
- Square wave, like police siren in the UK

FM modulation on the receive signal increases with distance. This smears out, or blurs, the Doppler signal. CW radar range detection involves FM demodulation to *sharpen* the Doppler signal by reducing the blurring like auto-focus on a camera.

The transmit frequency is used to down-convert the receive signal to baseband, and the amount of frequency shift between the transmit signal and the reflected signal increases with time delay (distance). FM Modulation index riding on the receive signal corresponds with range. Small frequency-spread is produced by nearby reflections. A larger frequency-spread corresponds with more time delay and a longer range. The amount of demodulation required to *sharpen up* the signal corresponds with distance.

Range demodulation is usually limited to 1/6 wavelength of the transmit modulation. Instrumented range for 100Hz FM modulation would be 250km. The radar is not guaranteed to report the correct distance for reflections from distances beyond the instrumented range.

Monostatic Radar

The radar receive antenna is located nearby the radar transmit antenna in monostatic radar.

Feed-through_null is typically required to eliminate bleed-through between the transmitter and receiver to increase sensitivity in practical systems. This is typically used with continuous wave angle tracking (CWAT) radar receivers that are interoperable with surface to air missile systems.

Interrupted continuous wave can be used to eliminate bleed-through between the transmit and receive antenna. This kind of system typically takes one sample between each pair of transmit pulses, and the sample rate is typically 30kHz or more. This technique is used with the least inexpensive kinds of radar, such as those used for traffic monitoring and sports.

Bistatic Radar

The radar receive antenna is located far from the radar transmit antenna in bistatic radar. The transmitter is fairly expensive, while the receiver is fairly inexpensive and disposable.

This is typically used with semi-active radar homing including most surface to air missile systems. The transmit radar is typically located near the missile launcher. The receiver is located in the missile.

The transmit antenna **illuminates** the target in much the same way as a search light. The transmit antenna also issues an omnidirectional sample.

The receiver uses two antennas - one antenna aimed at the target and one antenna aimed at the transmit antenna. The receive antenna that is aimed at the transmit antenna is used to develop the feed-through null, which allows the target receiver to operate reliably in or near the main beam of the antenna.

Advantage

Continuous wave radar are cheap enough for the average home budget. Some are small enough to carry in your pocket.

Because of their simplicity, CW radar are inexpensive to manufacture relatively free from failure, and cheap to maintain.

CW radars, such as Trackman[3] and Personal Pitcher[4], are inexpensive and are being used in sports to track ball and equipment parameters.

More sophisticated CW radar systems can reliably achieve accurate detections exceeding 100km distance while providing missile illumination.

Limitations

Unmodulated continuous wave radar cannot measure distance, and the beam is usually broad with side-lobes that extend to the side and behind the radar antenna . There is no way to determine which object corresponds with which speed measurement when there is more than one moving object near the receiver. Moving objects include birds flying near objects in front of the antenna. Reflections from small objects directly in front of the receiver can be overwhelmed by reflections entering antenna side-lobes from large object located to the side, above, or behind the radar, such as trees with wind blowing through the leaves, tall grass, sea surface, freight trains, busses, trucks, and aircraft.

Cheap unmodulated radar systems are only reliable when used with one object in a sterile environment free from vegetation, aircraft, birds, weather phenomenon, and other nearby vehicles.

With 20dB antenna side-lobes, a truck or tree with 1,000 square feet of reflecting surface behind the antenna can produce a signal as strong as a car with 10 square feet of reflecting in front of a small antenna that lacks directionality.

This is a typical problem with radar speed guns used by law enforcement officers, NASCAR events, and sports, like baseball, golf, and tennis. Interference from a second radar, automobile ignition, other moving objects, moving fan blades on the intended target, and other radio frequency sources will corrupt measurements. These systems are limited by wavelength, which is 0.3 meter at Ku band, so the beam spread exceeds 45 degrees if the antenna is smaller than 12 inches (0.3 meter). Significant antenna side-lobes extend in all directions unless the antenna is larger than the vehicle on which the radar is mounted.[5]

side-lobe suppression and FM range modulation are required for reliable operation. There is no way to know the direction of the arriving signal without side-lobe suppression, which requires two or more antenna, each with its own individual receiver. There is no way to know distance without FM range modulation.

Speed, direction, and distance are all required to pick out an individual object.

This limitations is well known among radar engineers.

Law enforcement agencies include hand held laser in the mix of tools needed for law enforcement to confirm reliable speed and position of an individual vehicle in traffic after radar detects excessive speed.[6] [7][8]

See also

- Doppler radar
- Fm-cw radar
- Pulse-Doppler radar

References

1. ^ "Continuous-wave Radar" (https://web.archive.org/web/20120418124039/http://www.fas.org/man/dod-101/navy/docs/es310/cwradar/cwradar.htm) . Federation of American Scientists. http://www.fas.org/man/dod-101/navy/docs/es310/cwradar/cwradar.htm.
2. ^ "Continuous-wave Radar" (https://web.archive.org/web/20120418124039/http://www.radartutorial.eu/02.basics/rp06.en.html) . Radartutorial.eu. http://www.radartutorial.eu/02.basics/rp06.en.html.
3. ^ "Trackman" (https://web.archive.org/web/20120418124039/http://trackman.dk/) . trackman. http://trackman.dk/.
4. ^ "Personal Pitchter" (https://web.archive.org/web/20120418124039/http://www.personalpitcher.com/) . Personal Pitcher. http://www.personalpitcher.com/.
5. ^ "Ranger EZ" (https://web.archive.org/web/20120418124039/http://www.mphindustries.com/radar_lidar.php?product=ranger) . MPH Industries. http://www.mphindustries.com/radar_lidar.php?product=ranger.
6. ^ "Stalker Hand Held Police Laser" (https://web.archive.org/web/20120418124039/http://www.stalkerradar.com/lidar_lr.shtml) . Stalker Radar. http://www.stalkerradar.com/lidar_lr.shtml.
7. ^ "Laser Speed Detector" (https://web.archive.org/web/20120418124039/http://www.digitalallyinc.com/speed-guns.html) . Digital Ally. http://www.digitalallyinc.com/speed-guns.html.
8. ^ "Speed Laser" (https://web.archive.org/web/20120418124039/http://www.mphindustries.com/radar_lidar.php?product=speedlasers) . MPH Industries. http://www.mphindustries.com/radar_lidar.php?product=speedlasers.

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